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Real-Time Environmental Arctic Monitoring (R-TEAM) Deployment Cruise

by

Peter R. Clay
Melbourne G. Briscoe

December 1988

Technical Report

Funding was provided by the Office of Naval Research through contract Number N00014-86-C-0135.

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Ocean Systems & Mooring Laboratory
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and

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Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

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Approved for Distribution:

Albert J. Williams 3rd

Albert J. Williams 3rd, Chairman
Department of Ocean Engineering

ACKNOWLEDGEMENTS

The R-TEAM mooring was designed, prepared and deployed by the Ocean Systems & Mooring Laboratory section of the Ocean Engineering Department. Members of the Applied Engineering laboratory of the Ocean Engineering Department designed and built the ascent module and the electronic controller. Defense Systems, Inc. of McLean, Virginia designed and built the medium frequency (MF) transmitter. Interfacing to in line instrumentation was completed by members of the Technical Support section of the Physical Oceanography Department's Buoy Group.

We want to thank Susan Tarbell for daily monitoring the ARGOS reception during and after deployment. Her confirmation of data reception in Woods Hole was a great reward for us all.

We are grateful to the Captain and crew of the R/V ENDEAVOR whose skill, expertise and enthusiasm were beneficial in the success of the experiment. We would also like to thank Teresa Shipley for her help in preparing this manuscript.

The constant support and keen interest given by Dr. Thomas Curtin to the R-TEAM program is also gratefully acknowledged.

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Introduction

The main purpose of the R/V ENDEAVOR cruise # 183 was to deploy the Real-Time Environmental Arctic Monitoring (R-TEAM) mooring in the Arctic for a period of one year.

The R-TEAM mooring is specifically designed to collect oceanic environmental data in the Arctic region and to transmit these data to shore on a daily basis via ARGOS satellite telemetry. To this end an ascent module comes to the surface once a day and transmits directly to ARGOS (ice free surface) or indirectly through a relatively close MF receiver station (ice covered surface). When not transmitting the module remains in its rest position most of the time, well away from the surface, thus diminishing the risks of damage at the ice interface. The design life of the R-TEAM system is one year <u>in situ</u>. The mooring must be capable of deployment in depths of up to 4500 meters and must be able to withstand a maximum current speed of 2 knots at the surface.

Important and novel components developed during the design and test period include:

- R-TEAM controller which performs all timing and control functions required in the operation of the mooring and also acts as the central data acquisition and <u>in situ</u> processing computer (acquisition of sensor data, buffering, and forwarding to transmitter.)
- R-TEAM power system, valve driver, MF power supply.
- MF and ARGOS transmitters and matching submersible antennae.
- All software for above electrical functions.
- SAIL/FSK pre-processor modules to permit interrogation by and data transfer between the controller and the sensors (current speed and direction, depth, water temperature and conductivity.
- Ambient noise sensor.
- Special electromechanical cables and highly reliable cable connectors to interconnect the sensors and the controller.
- Variable buoyancy system, control valves, and high pressure gas source (Liquid Co_2)
- Rigid, buoyant umbilical cable to provide electrical, mechanical, and pneumatic connection between the gas and power storage house in the mooring's main sphere and the ascent module.

All these components and their integration into subsystems were carefully and systematically bench tested, pressure tested, and near shore tested prior to their deployment at sea. (A. Bocconcelli, Real-Time Environmental Arctic Monitoring (R-TEAM) Interim Report. Woods Hole Oceanog. Inst. Tech. Rept., WHOI-87-50.)

Cruise Report

By

Peter R Clay, Chief Scientist

R/V ENDEAVOR 183
Tromso, Norway - Reykjavik, Iceland
August 21 - 30 1988

R-TEAM DEPLOYMENT CRUISE

CRUISE PERSONNEL:
H.O. Berteaux, Principal Investigator, WHOI
A. Bocconcelli, WHOI
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Ocean Systems & Mooring Laboratory
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WOODS HOLE OCEANOGRAPHIC INSTITUTION
Woods Hole, Massachusetts 02543

August 18, 1988

The R-TEAM deployment cruise to the Arctic was staged in Tromso, Norway on the R/V Endeavor. Personnel arrived on or around August 18, 1988 coinciding with the ship's arrival in port. Loading and pre-cruise preparations began on the morning of the 19th after the departure of the Harbor Branch science party. The controller and ARGOS transmitter had been operating on a test schedule during the transit from Narragansett and were found to be in readiness for the deployment. Refer to DSI Cruise report for details on communications electronics included in Appendix A. At 0808Z on Sunday, August 21,1988 the Endeavor departed Tromso on cruise EN-183.

August 22, 1988

At 1125Z ship slowed to 1.5 kts to perform the first ascent module up and down exercises and to test MF and ARGOS telemetry. These tests were delayed somewhat when the umbilical payout winch was irreparably damaged while attempting payout. Hand coiling the 220m umbilical on deck and then rewinding onto a winch on the 01 level permitted us to proceed. For these tests the controller was operated via its SAIL/FSK port allowing the controller to be commanded from the ship laboratory via the umbilical cable. These tests, at 74^{o} 28.5' N and 15^{o} 25.9' E, were successful although ascent times were alarmingly slow and the rest depth was 25m deeper than predicted (See Figure 1). At 1738Z we got underway again heading for Ny Alesund. At 1927Z, position 74^{o} 45' N and 14^{o} E, a release and CTD lowering to 1500m was started to acoustically exercise and test the primary mooring release as well as try a practice CTD cast. This was completed at 2055Z and we proceeded steaming North.

August 23, 1988

Wind and seas increased as a low passed to the south of us. Winds were up to Force 7 from the SSE, Sea State 4. During the next 24 hrs. this wind backed through south to southwest and gradually diminished.

August 24, 1988

Arrived in Kongsfjorden just off Ny Alesund at 0000Z. A small scientific party went ashore to observe the shore station and deliver some necessary electronic equipment for MF reception. A schedule of transmission tests while enroute to the mooring site and radio communications were also discussed with the shore station personnel. At 0103Z the scientific party boarded the ship and got underway steaming slowly to the

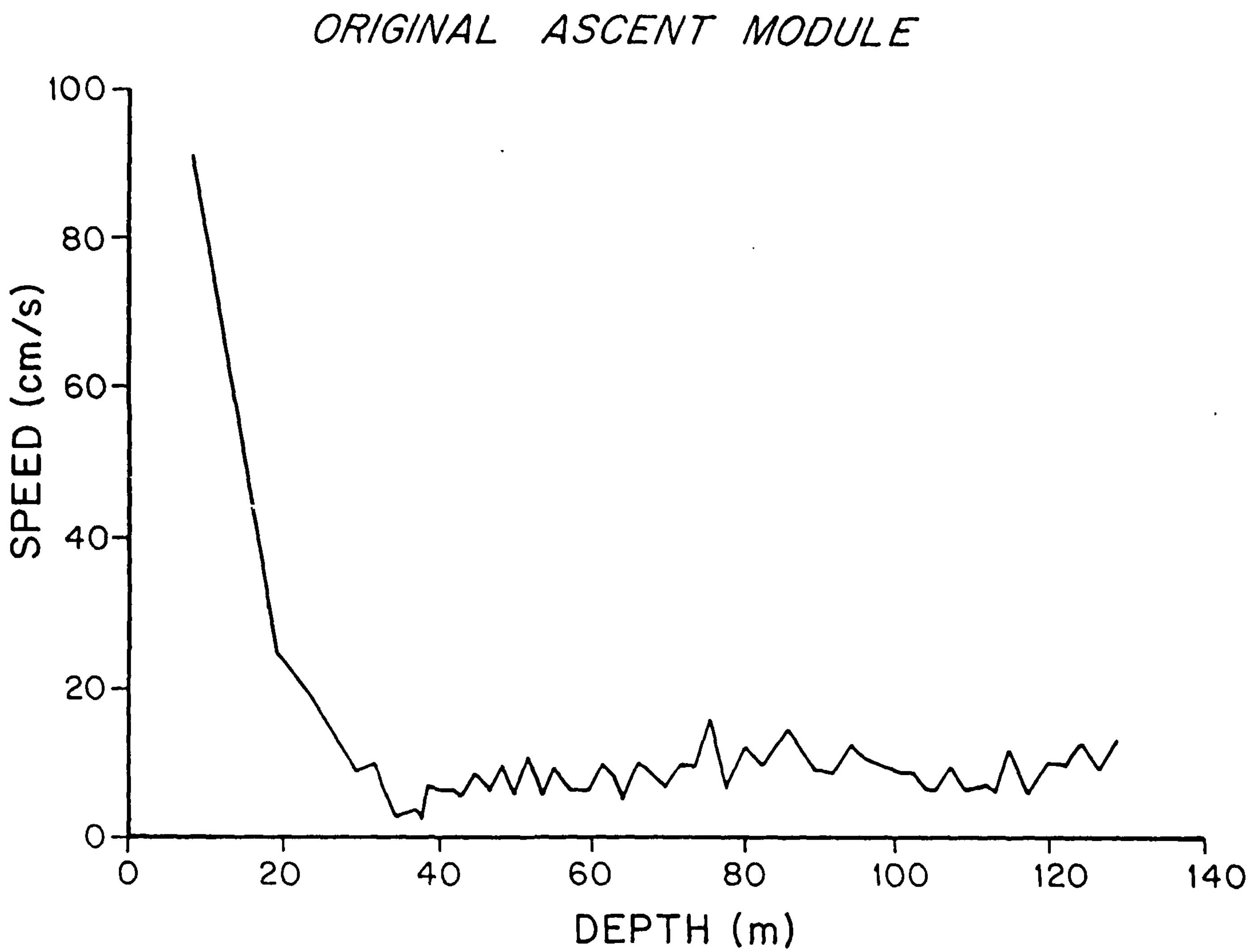

FIGURE 1 Module Ascent Speed Versus Depth (Original)

entrance of the fjord encountering many small icebergs.

At 0150Z the ship slowed to 1 kt to payout the module and establish a close range MF transmission data base (See Figure 2). The ascent module was reballasted by removing 10# of lead to meet our design rest depth. This change and increasing the gas valve on time to 120 seconds greatly improved the ascent rate of the module and provided ample buoyancy in the worst case, no current situation, to bring the module back to the surface (See Figure 3). Changing this time required removing the electronics to reprogram the EEPROM, which was done while enroute to the proposed drop site. At 1928Z the test was secured and the ship got underway.

While in Tromso, ice location in the vicinity of the proposed mooring site was obtained from French scientists of Laboratoire d'Oceanographie Dynamique et Climatologie (L.O.D.Y.C.) working at the Norwegian Satellite Telemetry Station of Tromso (See Figure 4). This information suggested that we would not be able to reach our originally selected location because of heavy ice cover. For this reason, the original mooring design, Figure 5, was modified at sea. The new design permitted deployment at a minimum depth of 1200m. In this way we were able to steam out to where we estimated the sea ice to be, survey the bottom, and then adjust the length accordingly to fit the site. This modified design, Figure 6, retained all the original E/M cable shots and therefore maintained the original nominal instrument depths of 100, 200, 500, and 1000m.

At 0840Z we again slowed to 1 kt to test MF transmission reception at a position half way to the site (about 30 miles from Ny Alesund). Although MF and ARGOS transmission from the ship were okay we were outside VHF communications range with the shore station, so we again got underway for our site departing at 0912Z not knowing if data had been received.

1142Z on station, depth 1225m uncorrected, position 79° 24' N and 6° 58.56' E. Checking set and drift of ship while steaming into the wind at 1.5 kts through the water to simulate deployment course and speed. Heading 165°, speed over the ground negligible, i.e. if we could hold our head to wind we could hold our position by steaming into the wind at 1.5 kts. We decided to steam downwind toward the ice pack to see if we could get closer to the ice and to check bathymetry.

1205Z underway at 10 kts, course 345°.

1230Z cross 1200m contour, position 79° 24.8' N and 6° 59.4'E.

1240Z, heavy ice ahead, slow to 5 kts and change course to 260° to cross 1300m contour to begin deployment.

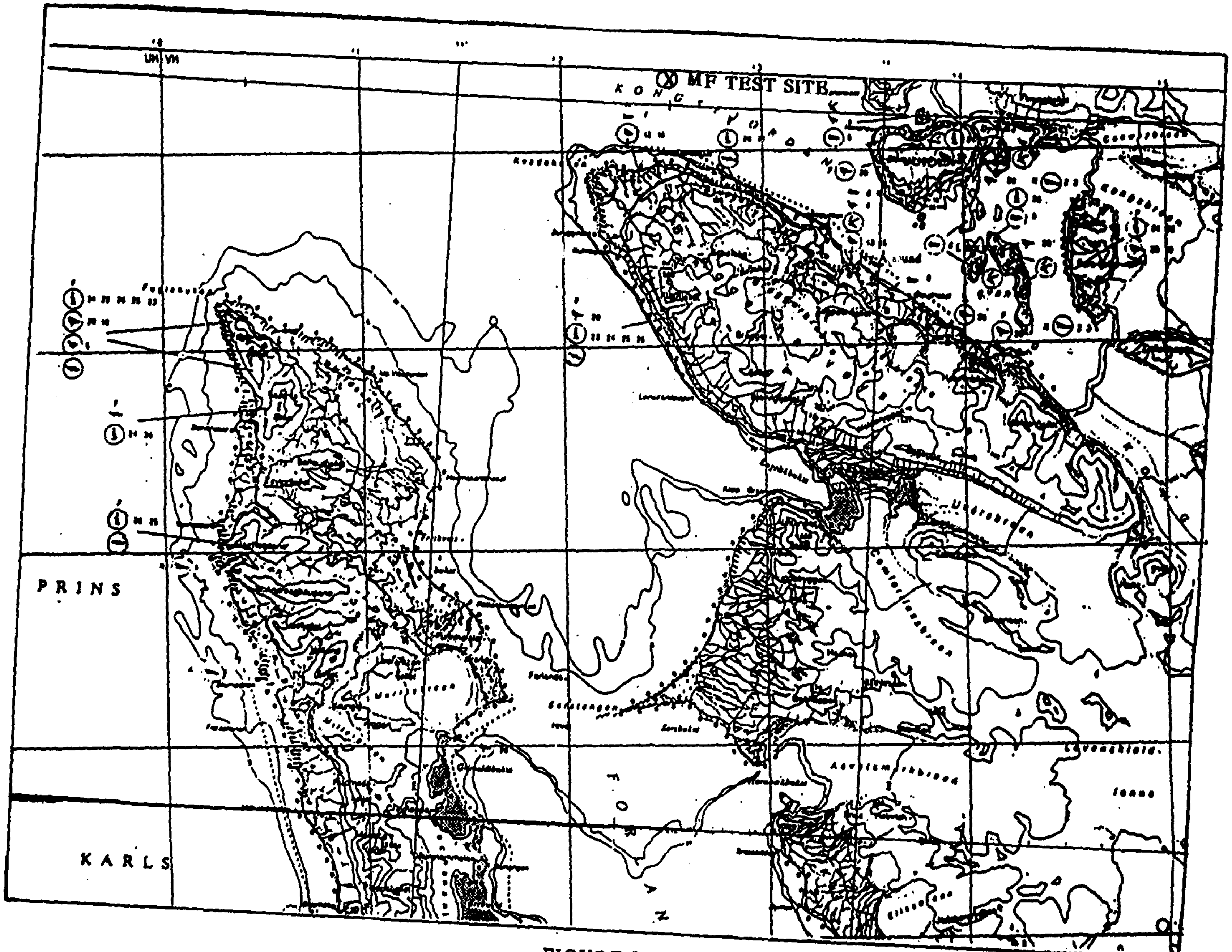

FIGURE 2
HF Close Range Test Site

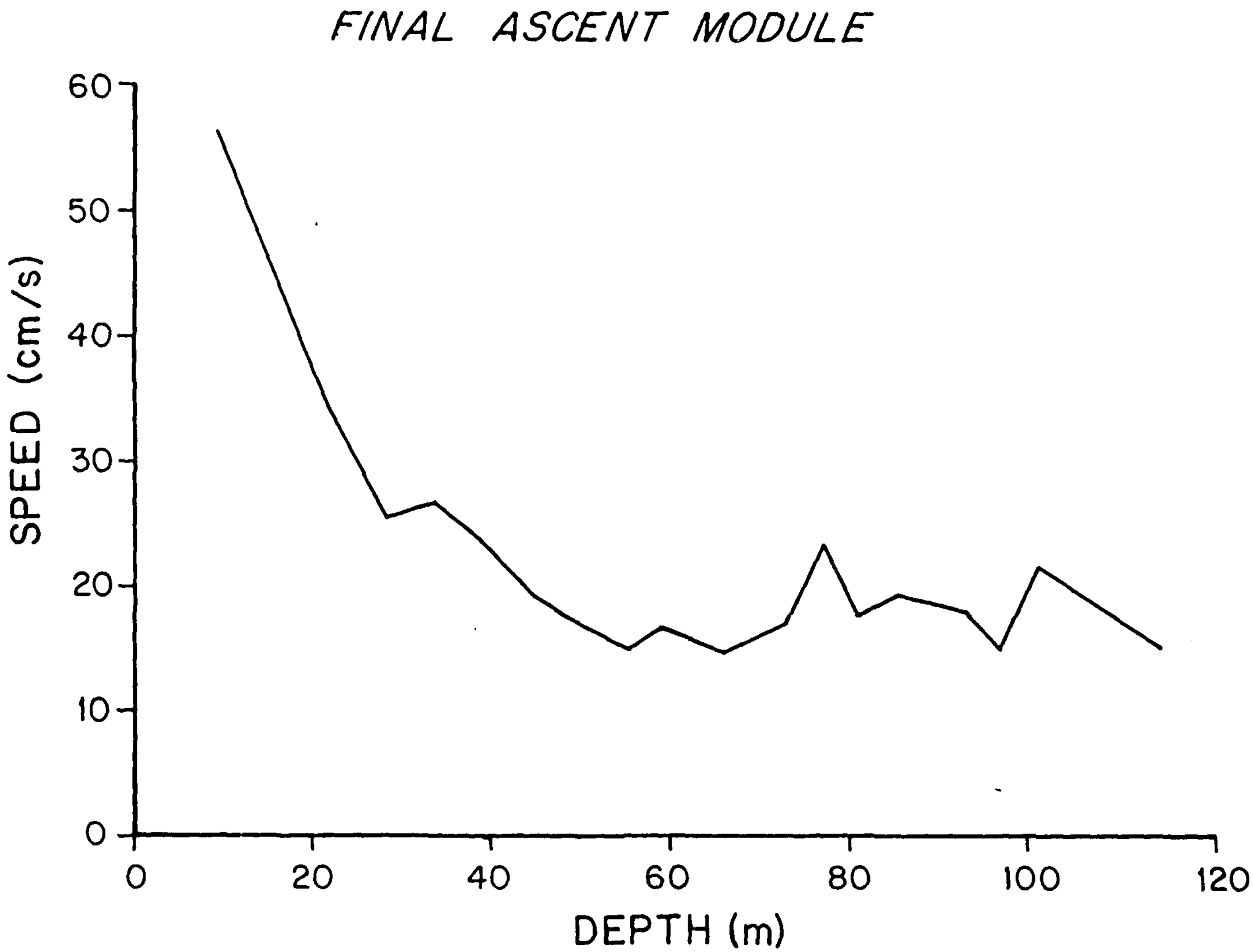

FIGURE 3 Module Ascent Speed Versus Depth (Final)

FIGURE 4
Ice Coverage Near Mooring Site

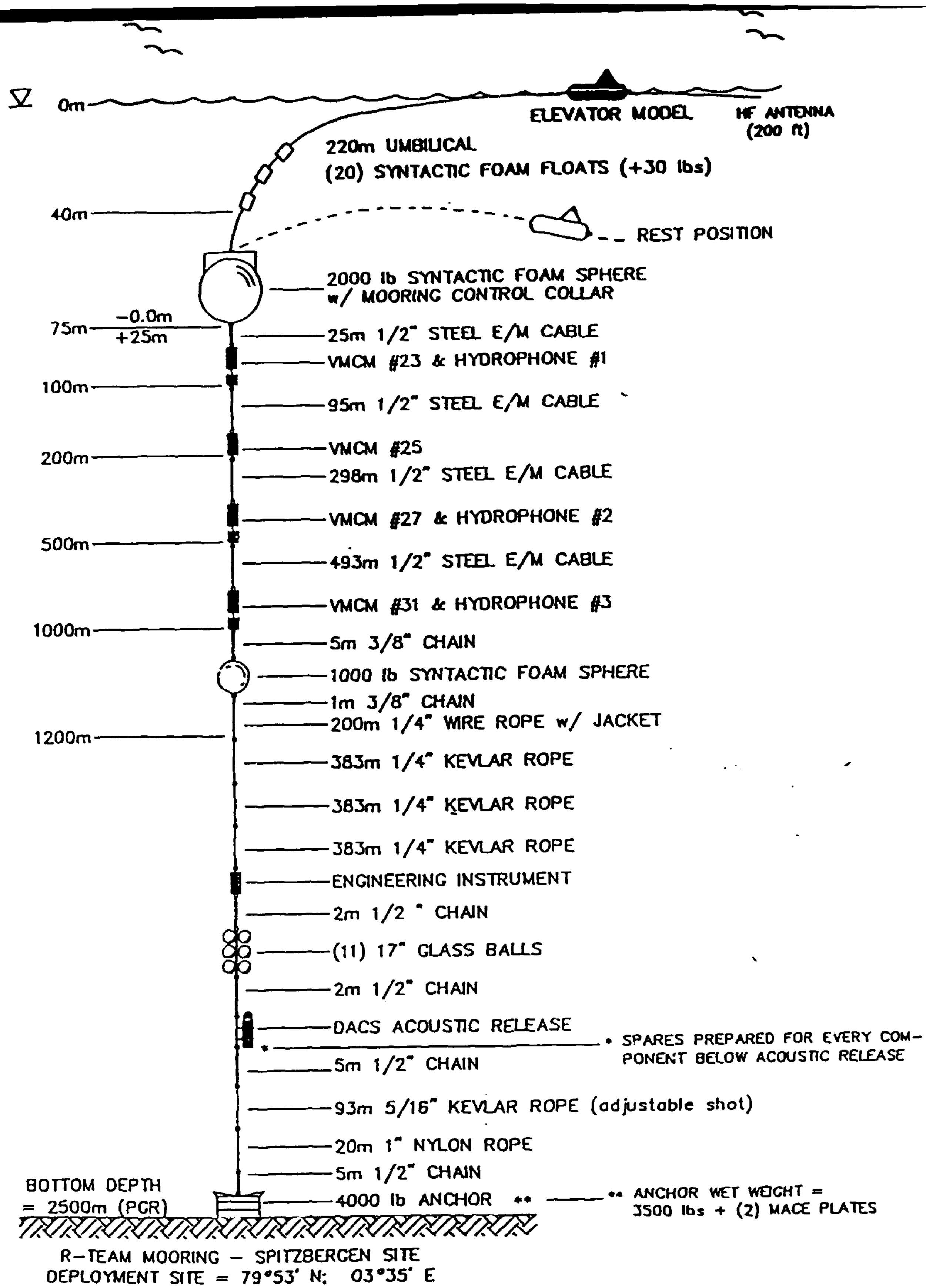

FIGURE 5
DEEP WATER DESIGN (2500m)

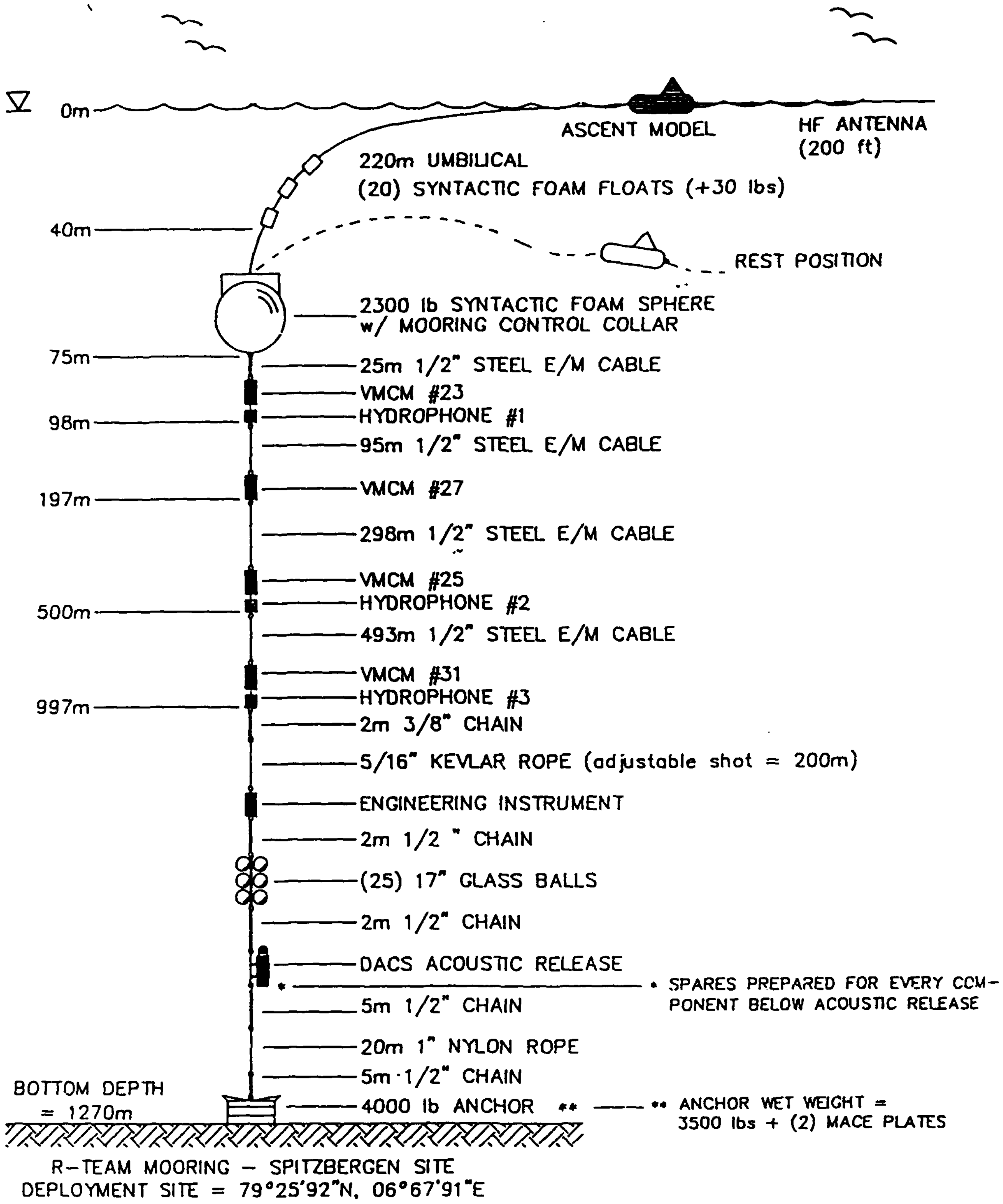

FIGURE 6
DESIGN AS SET (1270m)

1250Z cross 1200m contour again, 79^{o} 29.1'N and 6^{o} 50.1'E.

1315Z , cross 1300m contour 79^{o} 29.4'N and 6^{o} 41'E, change course to 165^{o} and slow to 2 kts to begin deployment.

1348Z start deployment with the polyform float and 250' polypro marker line attached to the MF antenna going over at 79^{o} 28.67' N and 6^{o} 41.72' E. The module was launched at 1355Z. The umbilical was slowly paid out having to stop to attach the 20 syntactic line floats 40m from the bottom end. At this point we again activated the ascent module going through a successful series of ascents and descents.

We then led the boot lower end down from the 01 level and attached it to sphere top stainless steel strength plate. This was accomplished by stopping off at the rail with a permanently installed Yale grip. The 25m shot of E/M cable, top VMCM, hydrophone, and the 95m shot of E/M cable were all connected in line ready for deployment. FSK communication with the controller via the top VMCM verified cable and connector integrity to this point, plus proper connection of the 45V battery supply in the subsurface float.

At this point our progress along the proposed deployment track was much further than expected. Six hours had been allotted for deployment, but after three hours we were at the drop site with only a fraction of the mooring out. We elected to swing around and tow the top mooring section back along the track we had just traveled on. Slow progress was made even while steaming at 3 kts through the water presumably because a 1.5 kt tidal current had turned on us part way through the deployment. When we approached the ice again we made a turn to 165^{o} and proceeded with the deployment of the large sphere.

Deployment of the large sphere, CO_2 tanks, battery packs, and floatation collar went smoothly. The 25m E/M cable below the sphere lay slack on deck. Back aft under the A-frame outrigger the top VMCM Hydrophone assembly was ready for quick deployment to reduce dynamic shock loads in the relatively short 25m shot of E/M cable. Sphere deployment was performed using the ship's crane, quick release hook and slip lines led to maintain control. With 1.5 kts of boat speed, the sphere slowly drifted astern giving us time on deck to lower the VMCM and hydrophone over the stern using an air tugger so that we could pay out the 95m wire shot as the sphere pulled astern giving ample catenary to absorb any relative motion between ship and sphere. Although hectic because of a fouled line, this procedure went quite smoothly.

Deployment proceeded uneventfully after this point. Each E/M cable connection was done by first stopping off using Yale grips previously attached and then connecting up to D.G. O'Brien connectors with spanner wrenches and locking set screws. Inspection of proper o-ring seating was also checked at every termination with the exception of the last one which had not been completely machined, lacking both o-ring observation holes and set screw hole threads. Additional spanner wrench torsion was applied and the lock nut heavily taped to prevent premature backing off.

At the last VMCM the line was again stopped off for the final electrical tests, FSK communication was verified to all four VMCM's and to two of the three hydrophones, hydrophone #1 not responding to manual interrogation for unknown reasons. A decision was taken to proceed with the deployment, so at 1834Z a software reset was sent to the controller. The R-TEAM application auto-booted at 1835Z and successful interrogation of all seven sensors (including hydrophone #1) was observed from our vantage point at the last (bottom) VMCM in the line.

Deployment of the remainder of the mooring then proceeded smoothly. The anchor was dropped at 1734Z on August 24, at 79° 25.92' N and 6° 47.91' E in 1300m (uncorrected) of water (See Figure 4). Additional information on the mooring deployment can be obtained by referring to the mooring Station Log included in Appendix B.

After ensuring the release had bottomed out, we steamed off to the east, 1 mile for a CTD cast to 1250m. The data obtained from this cast was used to obtain an actual sound velocity at the site to determine final instrument depths and also for data comparisons of telemetered data received back at Woods Hole. In order to accurately locate the mooring position, ranges to the release were obtained while lowering the CTD. These acoustic slant ranges were converted to horizontal ranges and were taken at the time of new satellite fixes. Swinging these horizontal ranges from well-known positions gave a good mooring position. Actual water depth after applying the corrected sound velocity obtained from the CTD was 1270m. This corrected water depth and 200m adjustable Kevlar length put the main sphere at 73m and the current meters at 98, 197, 500, and 997m.

Immediately after the CTD cast, we steamed back to the mooring site arriving there in heavy fog at about 2130Z. We were unable to locate the polyform marker float visually, so we tracked our progress acoustically by ranging to the release.

By slowly changing the ship's heading at slow speed we were able to close on the mooring. At the first closest point of approach, the marker buoy was sighted to starboard at a range of about .25 N.M. Our approach luckily coincided with a transmission so the module was on the surface. It was our intent to remove the marker buoy and watch a couple more ascents before leaving the site. As we approached the buoy, sea ice to the south about .25 N.M. away was drifting down on the module at about one knot. We quickly came alongside the marker float and polypro and retrieved the line cutting it off at the end of the 200 ft antenna. This was completed at 2208Z on August 24. Before the module descended at 2214Z, ice pieces from the loose sea ice nudged the module with a surface velocity of about 1 kt. Photographs, although taken in the midnight sun, will hopefully show this first ice assault only hours after launch.

While on station, all MF and ARGOS transmissions were received onboard. Phone patches through Svalbard Radion to the Ny Alesund shore station had the exciting news that good strong signals were being received. Similar phone patches to Woods Hole also had the good news that ARGOS data was being successfully received as well.

2320Z got underway for Reyjavik, Iceland via Jan Mayen Island.

Cruise Report

By

Melbourne G. Briscoe

R/V ENDEAVOR 183
Tromso, Norway - Reykjavik, Iceland
August 21 - 30 1988

R-TEAM DEPLOYMENT CRUISE

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Introduction

The Real-Time Environmental Arctic Monitoring (R-TEAM) mooring was scheduled to be set in the Fram Strait, between Svalbard and Greenland, from the R/V ENDEAVOR in late August 1988. Although my association with the R-TEAM project had become minimal since the start of my two-year Intergovernmental Personnel Agreement (IPA) position at ONR in December 1987, I was still the only physical oceanographer that was part of the program, and I was likely to be a principal in the analysis of the data after the recovery of the mooring in 1989.

Consequently, I made arrangements to join the deployment cruise with the responsibility for:

(a) On-board scientific input.
(b) Conductivity-temperature-depth (CTD) profiling.
(c) Bathymetry at the deployment site.
(d) Ship maneuvering during deployment.
(e) Communications with the base at Svalbard.

Topic (b) was motivated by my having the equipment and experience to make a CTD profile at the deployment site, with minimal expense and effort. The Seabird "Seacat" CTD that had been obtained in 1986 for the RiNo float in PATCHEX had been modified during 1987 to be a profiler, and was small enough to be hand-carried from Woods Hole to Tromso to join the cruise. The Zenith 181 laptop computer that Texas A & M had purchased for my use on a WOCE planning project was available to be hand-carried as well, and was to be the data acquisition and analysis computer. The importance of the CTD effort was three-fold:

1. Temperature and conductivity data were needed to confirm that the sensors on the R-TEAM mooring were performing properly.

2. Sound speed data were needed to correct the bathymetry records, so that the length of the mooring was correct for the water depth.

3. Density profiles were needed to permit the mooring data to be interpreted scientifically.

Topic (c) was required because the depth of the top of the mooring had to be between 75 and 100m from the surface. Although the available charts of the Fram Strait topography were reputed to be fairly accurate, navigation in the area was marginal (satellite plus distant Norwegian Loran stations) and it might not be possible to put the mooring in the most desirable (i.e. flat) sites, depending on the ice conditions at the time. The scientific party scheduled for the deployment cruise was not much experienced in bathymetric surveying.

Topic (d) was related to topic (c); good bathymetric knowledge was useless unless the ship could be guided to the right spot at the right time. I have had ten years of experience in precision mooring setting in conditions ranging from flat bottoms and no currents to Gulf Stream currents and sloping bottoms, with all kinds of moorings (e.g. subsurface, spar, surface, deep and shallow). Setting near an ice field sounded like an interesting experience.

Finally, topic (e) was based on my amateur radio and at-sea communication experience. Our man ashore at Svalbard (Bob Summers, from Defense Systems Inc.) needed to be talked to during the tests of the MF (called HF within the R-TEAM project, but at 537.5kHz it is really Medium Frequency) telemetry from the buoy; my general experience in telemetry under the WHOI University Research Initiative would prove to be valuable as well.

Brief Chronology of Events

August	16	Departed Washington D.C. for Tromso.
	17	Arrived Tromso. R/V ENDEAVOR arrives.
	18	Unpacked Seacat CTD; system test.
	19	Visited French satellite lab; obtained ice info.
	20	Prepared working area. Assisted others.
	21	Departed Tromso at 0805Z (1005 local).
	22	CTD profile along with acoustic release test.
	23	Analyzed CTD data. Changed batteries in CTD.
	24	0000Z: Went ashore at Ny Alesund, (Svalberg). Spoke with B. Summers and arranged communications. 0200Z: Ascent module tests in Kongsfjorden 1240Z: Arrived at ice edge (79°29.5' N and 6°50.1'E). Began final bathymetry runs, and site selection. 1400Z: Began deployment. 1933Z: Anchor in at 79° 26' N and 6° 48' E. 2020Z: CTD station.

	2100Z: Observed ascent module perform at edge of ice.
	2320Z: Underway to Reykjavik via Jan Mayen.
25	Analyzed CTD station.
26	Worked up corrected sound speeds. Started cruise report.
27	Hove to in Force 9 seas near 69° N and 16° W.
28	Hove to in Force 9 seas near 68° N and 20° W.
29	Completed cruise report.
30	Arrived Reykjavik.
31	Departed Reykjavik for Washington D.C. via Boston.

Bathymety and Site Selection

The mooring site was constrained by several requirements:

- Under ice during the winter.
- Ice-free now and next summer.
- Depth 1065-3000m
- < 100 miles from Ny Alesund, 60 miles even better.
- Between 296° and 328° bearing from Ny Alesund.

The under-ice requirement was the highest priority; if the mooring were not going to be under ice, then it could go in much closer and easier-to-get-to places than the Fram Strait. The ice-free now and next summer requirement is obvious, except that guessing about next summer is a risky game to play.

The depth requirement was based on the placement of the instruments along the mooring line at 100, 200, 500, and 1000m beneath the surface. The mooring could be shorter than 1000m, but the lower instruments would have to be removed. Including release length, etc.; 1065m (corrected depth) is the minimum depth for an unmodified mooring.

The distance and bearing from Ny Alesund is based on the capability of the MF (537 kHz) radio link from the mooring to the shore station at the Norsk Polar Institut at Ny Alesund. The range is calculated from system specifications and could be quite variable; the bearing is determined by a clear view up the Kongsfjorden between quite high hills/mountains.

An additional constraint that is hard to quantify is based on the radiation pattern of the MF floating-wire antenna on the R-TEAM ascent module. The antenna works best as an end-fire array, and falls off about as a cosine until broadside where there is no radiation. Thus, if the mooring wre located due west of Ny Alesund, and the current were stretching out the wire antenna in a north-south direction, no signals would be received at the shore station. This argues for putting the mooring as far north as possible so the generally southerly currents will give as much of an end-fire configuration as possible. However, we also anticipate the currents to be quite variable, and the surface currents to be very wind dependent. Hence, this constraint was not really addressed.

The Raytheon Line Scan Recorder (LSR) was turned on when we left the sheltered waters outside Tromso fjord, and turned off when we neared Reykjavik. It ran at 0-1500m (uncorrected) full scale for the duration, with automated time marks every 15 minutes. During the August 23-25 period near Svalbard, considerable extra annotation was added to correspond to positions, events, and course changes.

Note that the R/V ENDEAVOR SAIL system was running throughout the cruise, with complete navigation, meteorology, and sea-surface temperature and conductivity logged every ten minutes. The logging is on both printout and 3 1/2 inch HP-85 format disks. I have a conversion program at WHOI from Oswego Software that will convert HP-85 format to IBM-PC format.

The R/V ENDEAVOR carried the British Admiralty update to the venerable Matthews' tables for the correction of LSR records. Matthews' tables stop at 75° N, but suggest that Area 1 is appropriate in the entire region north of Bear Island. For 1000m indicated depth, Area 1 suggests the actual depth is 968m. The new tables (Carter, D.J.T., 1980 Echo-Sounding Correction Tables, Third Edition, NP 139, Hydrographic Department, Ministry of Defense, Taunton) shows the region from 79-81° N, 6-9° E to be Area 4, with Area 2 just to the west of that region. In Areas 2 and 4, 1000m uncorrected would be 974 and 976m, respectively, corrected. Thus, the range of urcertainty is about 8m in 1000m.

As it turned out, the sound speed profile described below gave an average sound speed in the top 1000m of 1461m/s, hence the actual depth corresponding to 1000m uncorrected is 974m. Empirically, our mooring site seems best described by Area 2 in the new tables, even though geographically it is in Area 4. In Area 2, 1300m uncorrected is 1266m corrected. (In Area 4 it is 1269m corrected.) The actual corrected depth based on the measured sound speed profile (see below) was 1267m, plus 3m for the depth of the transducer beneath the hull. Thus, 1300m indicated is 1270m actual.

The ice information obtained from the French research team in Tromso was accurate and valuable. They had examined AVHRR images from NOAA 9 for August 12 and 16, and had transcribed ice positions to a chart of Svalbard and the Fram Stait. Their experience in interpreting these images allowed them to differentiate between pack and loose ice, and to estimate ice movement directions. Based on their chart, we were not going to be able place the mooring at the northernmost default position of 80° N and 20° E, or at the first-choice default position of 79° 30′ N and 3° 30′ E.

Ship Maneuvering

After leaving Kongsfjorden and Ny Alesund, we steamed northwest toward the ice. The game plan was to verify the ice position as shown in the French chart, then to set the mooring as near to the ice as practical while still satisfying the depth and other criteria.

From the ice chart and our bathymetric information, we estimated that setting on the 1300m (uncorrected) isobath a few miles from the ice would be the best position. This is precisely what happened. After some time in determining the set of the ship due to local winds and currents, we steamed southwest from the ice edge along the 1300m (uncorrected) isobath at 1.5 kts through the water.

1300m was chosen because the corrected depth was between 1264 and 1269m, depending on the the source book and area selected; to this you must add 3m for the depth of the ship's transducer beneath the surface. Thus, the water depth along the indicated 1300m isobath was actually 1267 to 1272m. The stretched mooring length was 1195m, plus 75m from the top float to the surface, or 1270m total. As it turned out (see below), the actual water depth was 1270m along the indicated 1300m isobath, although we did not know that at the time of setting because the CTD profile had not yet been made.

In the light winds and low currents and sea state, maintaining the ship heading and speed was not difficult. The objective was simply to keep the ship speed through the water at about 1.5 kts, and to modify the ship heading as necessary to maintain our movement along the indicated 1300m isobath. A few 5° heading changes were necessary to do this; we began the setting steaming 165° true; we ended steaming 150° true.

The anchor-drop position at August 24 at 1933Z was logged on Loran as 79^{O} 24.7' N and 6^{O}47.2' E. The previous satellite fix was at 1924Z, which its internal dead-reckoning had updated to 79^{O} 26.2' N and 6^{O} 48.3' E at 1932Z. For reference, the 1950Z sat fix was 79^{O} 25.92' N and 6^{O} 47.91' E, at which time the Loran fix was 79^{O} 23.80' N and 6^{O} 46.52' E. This suggests the Loran fixes are 2.13 N.M. south and 0.26 N.M. west of the satellite fixes. If this correction were applied to the 1933Z Loran position, the inferred anchor-drop satellite position would be 79^{O} 26.8' N and 6^{O} 47.6' E; this is 0.6 N.M. north of the satellite navigator's dead-reckoning position. Note that Peter Clay's "official" anchor position based on transponding to the release from known satellite fix positions, is 79^{O} 25.92' N and 6^{O} 47.91' E. This includes the fall back of the anchor along the stretched-out mooring. This fall back is typically 15% of the mooring length, or 180m (0.1 N.M.) in this case. If the mooring were stretched out along 160^{O} true, then the anchor-drop position would fall back to about 79^{O} 26.9' N and 6^{O} 48.4' E based on the inferred satellite anchor-drop position, or to about 79^{O} 26.3' N and 6^{O} 48.1' E based on dead-reckoned satellite fix, or to about 79^{O} 24.6' N and 6^{O} 47.0' E based on the Loran anchor-drop position. These positions are tabulated below.

Anchor-drop (Loran)	79^{O} 24.7' N and 6^{O} 47.2' E
Anchor-drop (DR SATFIX)	79^{O} 26.2' N and 6^{O} 48.3' E
Anchor-drop (SAT-Loran offset)	79^{O} 26.8' N and 6^{O} 48.6' E
Anchor (Loran)	79^{O} 24.6' N and 6^{O} 47.0' E
Anchor (DR SATFIX)	79^{O} 26.3' N and 6^{O} 48.1' E
Anchor (SAT-Loran offset)	79^{O} 26.9' N and 6^{O} 48.4' E
Anchor (Peter Clay)	79^{O} 25.9' N and 6^{O} 47.9' E

All these positions lie within 4300m of each other, so there will be no problem with the recovery of the mooring, but the existence of the disparity shows the problems of navigation in the area.

CTD Profiles

The Seabird CTD was used twice: once on August 22 at 1936Z near 79^{o} 46′ N and 14^{o} 27′ E (1845m uncorrected depth) as part of the release test, and once on August 24 at 2020Z near 79^{o} 27.6′ N and 6^{o} 51.8′ E (1250m uncorrected depth) near and just after the mooring deployment.

In both cases, the CTD was affixed to the hydrographic wire by about a 1.2m pigtail of wire rope fastened with Crosby clips just above the bitter end of the hydro wire. The pigtail had a thimble in it that was shackled to the upper end of the CTD. The segment of hydro wire adjacent to the CTD was covered with a slit piece of garden hose to protect the CTD from chafing. The lower end of the CTD was tied with a length of dacron line to the shackle in the end of the hydro wire. Plastic tie-wraps were used to secure the CTD to the hydro wire to keep everything snug. This rigging was used during the release test so that the release could be shackled to the end end of the hydro wire with a lead weight beneath it; the same rigging was used for the station near the mooring, but with the lead weight just shackled directly to the end of the hydro wire. In this way, the weight of the lead was not being supported by the case and tie rods of the CTD.

For both stations, the CTD was started in the lab (with the GL command) and carried out to the hydro wire to be fastened on. The tygon tubing with deionized water in it was pulled off immediately before the CTD was put over the side. When the CTD entered the water, it was held at the surface for about a minute to let its temperature equilibrate. For the release-test station, the lowering was at 60m/minute with holds for a few minutes at 200, 500, 1000, and 1500m of wire out; the ascent was at 100m/minute. For the station near the mooring, the descent was at 40m/minute to 200m wire out and then 60m/minute to 1250m of wire out; the ascent was at 80m/minute.

In both cases, the CTD was unshackled from the hydro wire and brought into the wet lab to be rinsed off with fresh water in the sink. The tygon tube with deionized water was reinstalled, and the CTD was then dried off and brought into the main lab to have its memory dumped. The PROTERM function key 9 cast-dump was used both times. The attached figures and table show the following results:

August 22, 1936Z: 79^{o} 46′ N and 14^{o} 27′ E (1845m uncorrected depth)
(down cast data, no averaging)

A. temperature versus pressure
B. sound speed versus pressure

C. temperature versus salinity

August 24, 2020Z: 79° 28′ N and 6° 52′ E (1250m uncorrected depth)
(down cast data)

D. temperature versus pressure, no averaging
E. conductivity versus pressure, no averaging
F. salinity versus pressure, no averaging
G. sigma-theta versus pressure, no averaging
H. sound speed versus pressure, no averaging
I. salinity versus pressure for just the top 50m, no averaging
J. temperature and conductivity versus pressure for 2 decibar averaged data
K. salinity and sound speed versus pressure for 2 decibar averaged data
L. tabulated 10 decibar averages for the top 120m and the depths near the instruments on the mooring

The calculation of average sound speed was performed using the BINAVG program provided in the SEASOFT 3.0 package. Various bin sizes were used to cover the depth range. The calculation was complicated by the BINAVG technique of assigning points to a bin: if the bin size were 100m bin then BINAVG would assign all the points from 50 to 150m into the 100m bin. This makes it difficult to do the desired, namely to average the points between 3m and the bottom. (The top is 3m because the ship's transducer is at that depth.) Consequently, the following scheme was used:

depth range	layer thickness	avg sound speed
3 - 5m	2m	1461.13m/s
5 - 15	10	1463.02
15 - 45	30	1472.10
45 - 135	90	1462.31
135 - 405	270	1459.90
405 - 675	270	1460.41
675 - 945	270	1460.79
945 - 1215	270	1462.90
	1212m	1461.39m/s

To this was added an additional 1215 - 1300m contribution estimated from the 1150 - 1250 and 1250 - 1350 BINAVG values of 1464.44m/s and 1465.72m/s, respectively. This suggested a 1.28m/s per 100 meters sound speed gradient at the bottom of the profile, hence the bottom 85m would have an average sound speed of 1465.53m/s. The final averaged sound speed for the bottom 1297m of a 1300m layer was 1461.66m/s. Therefore, 1300m uncorrected depth based on 1500m/s would really be 1461.66/1500m * 1300m = 1267m.

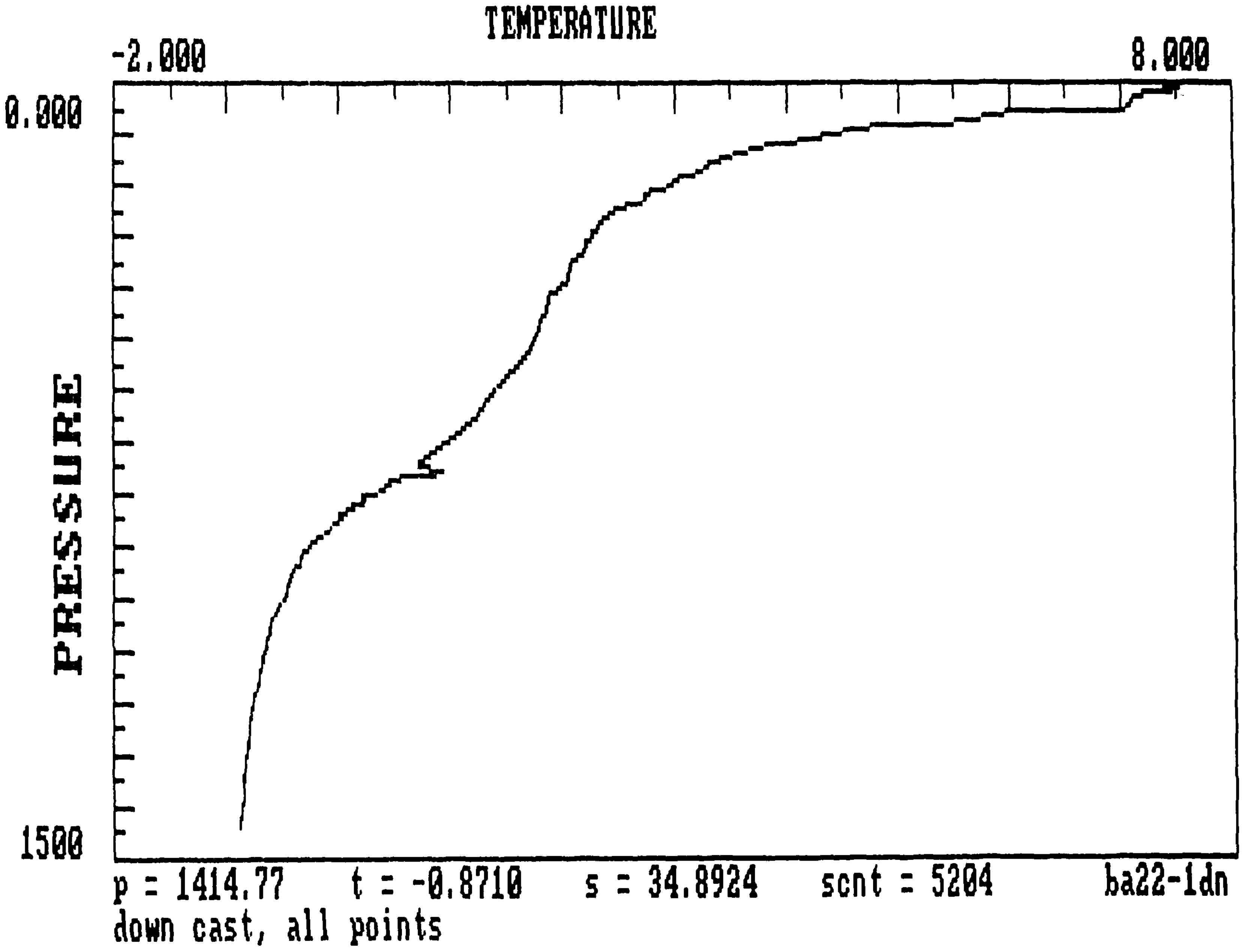


FIGURE A Temperature Versus Pressure

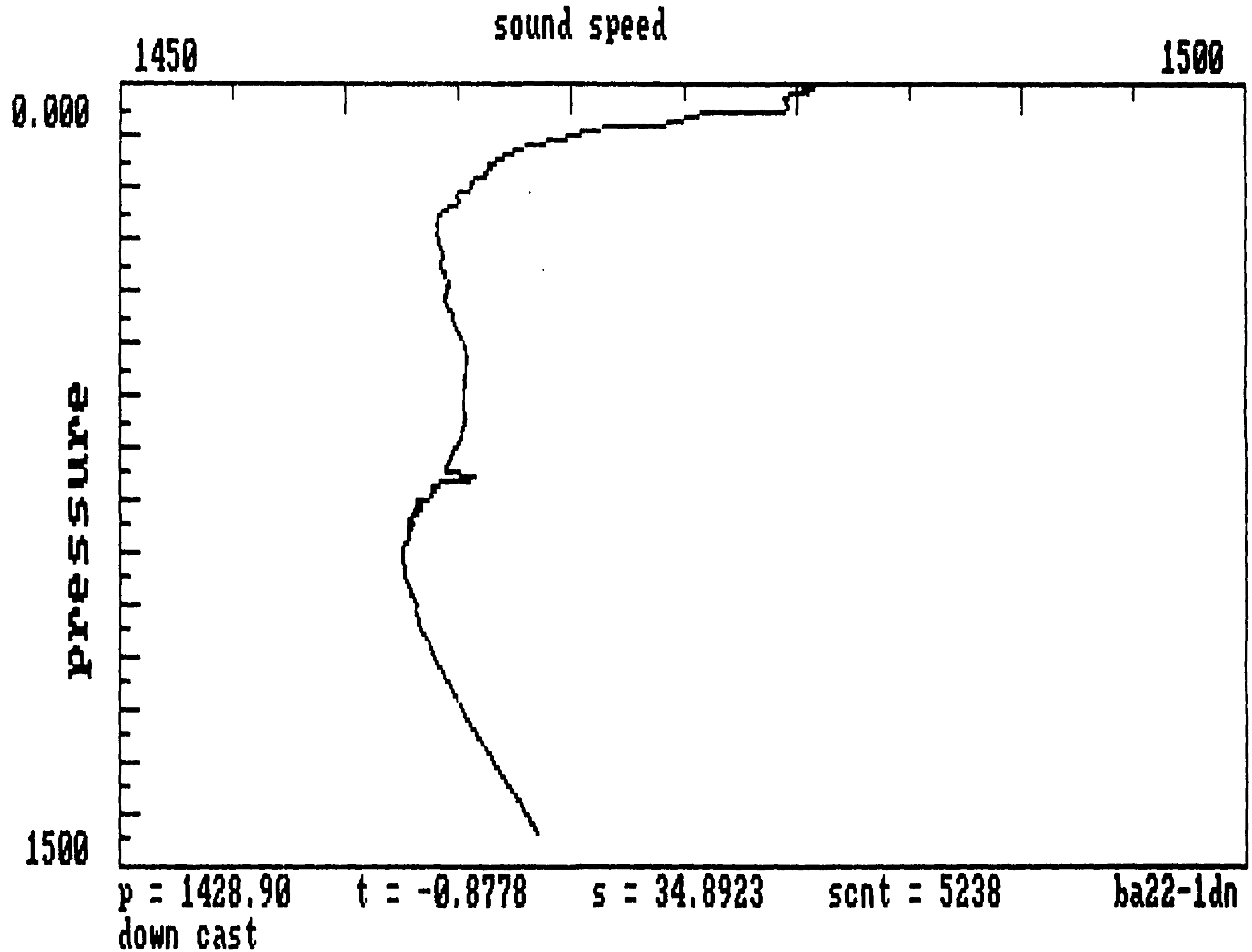


FIGURE B Sound Speed Versus Pressure

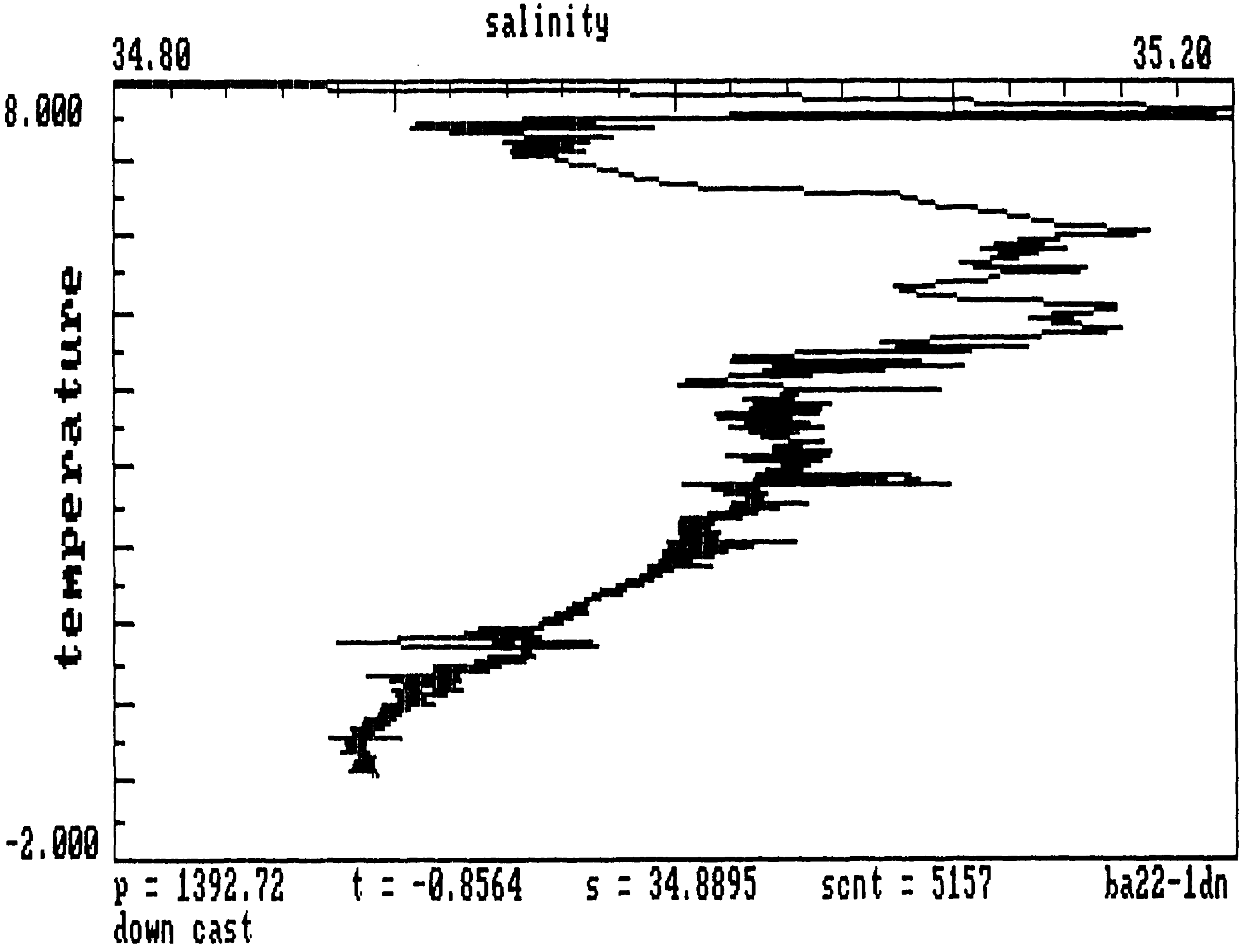


FIGURE C Temperature Versus Salinity

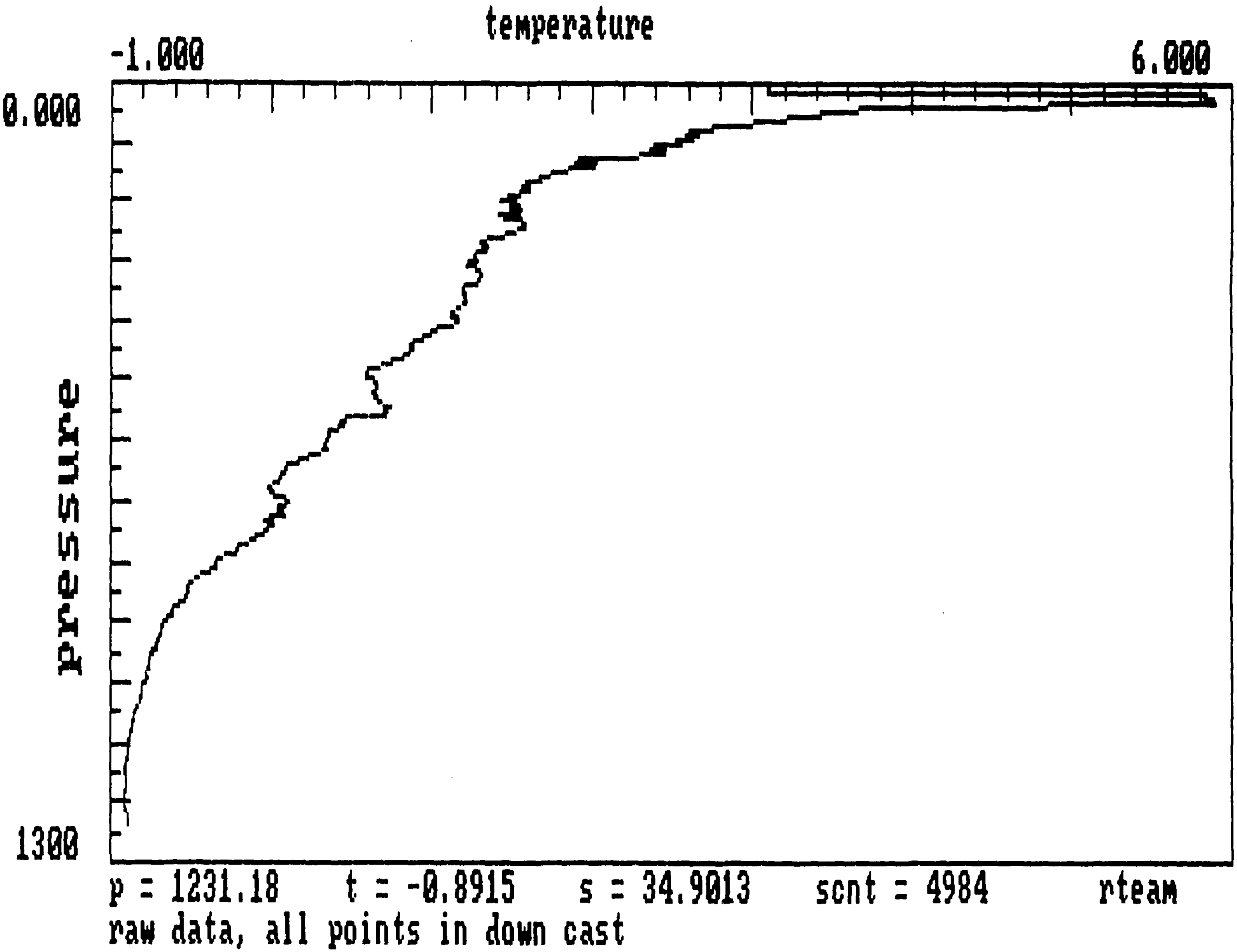


FIGURE D Temperature Versus Pressure, No Averaging

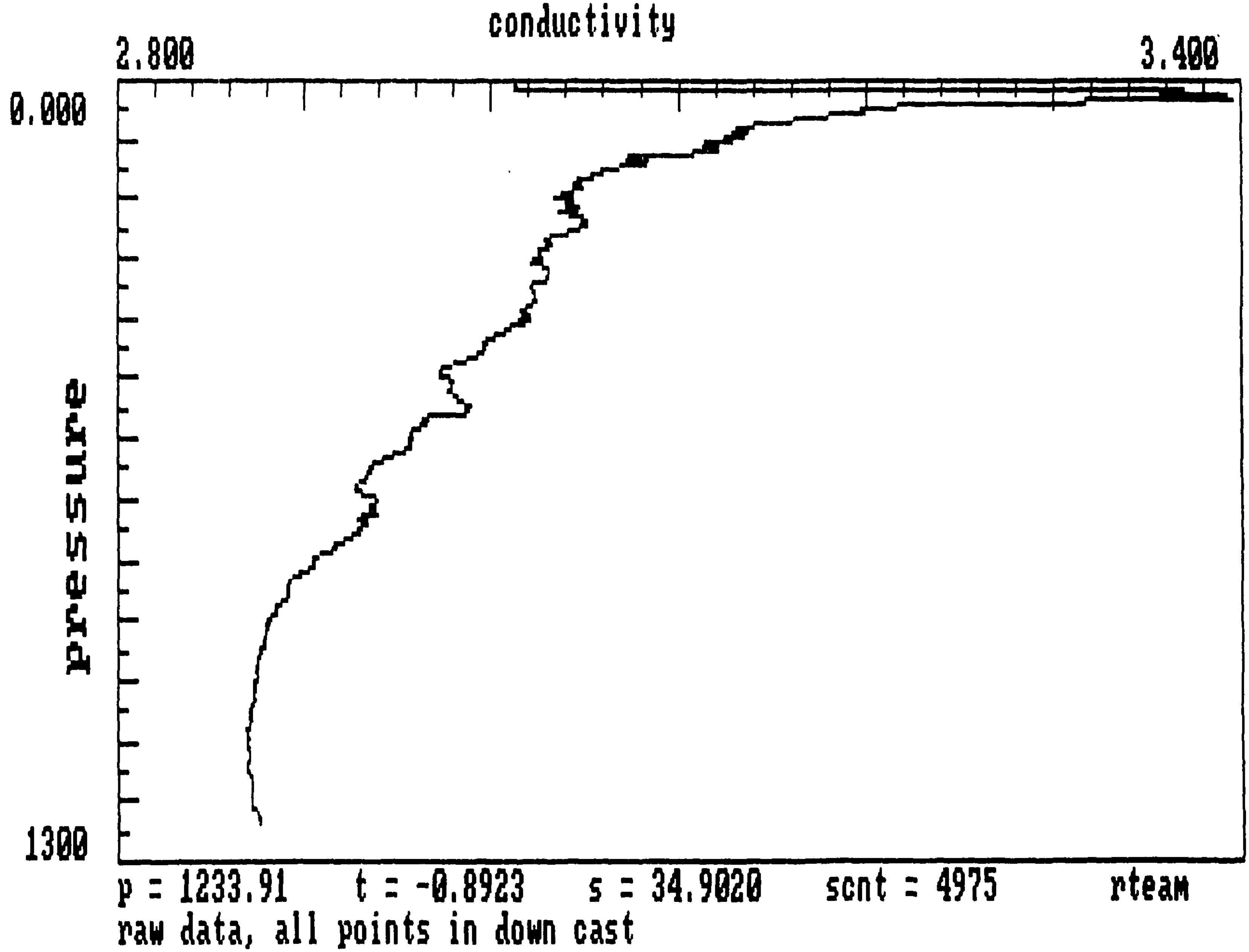


FIGURE E Conductivity Versus Pressure, No Averaging

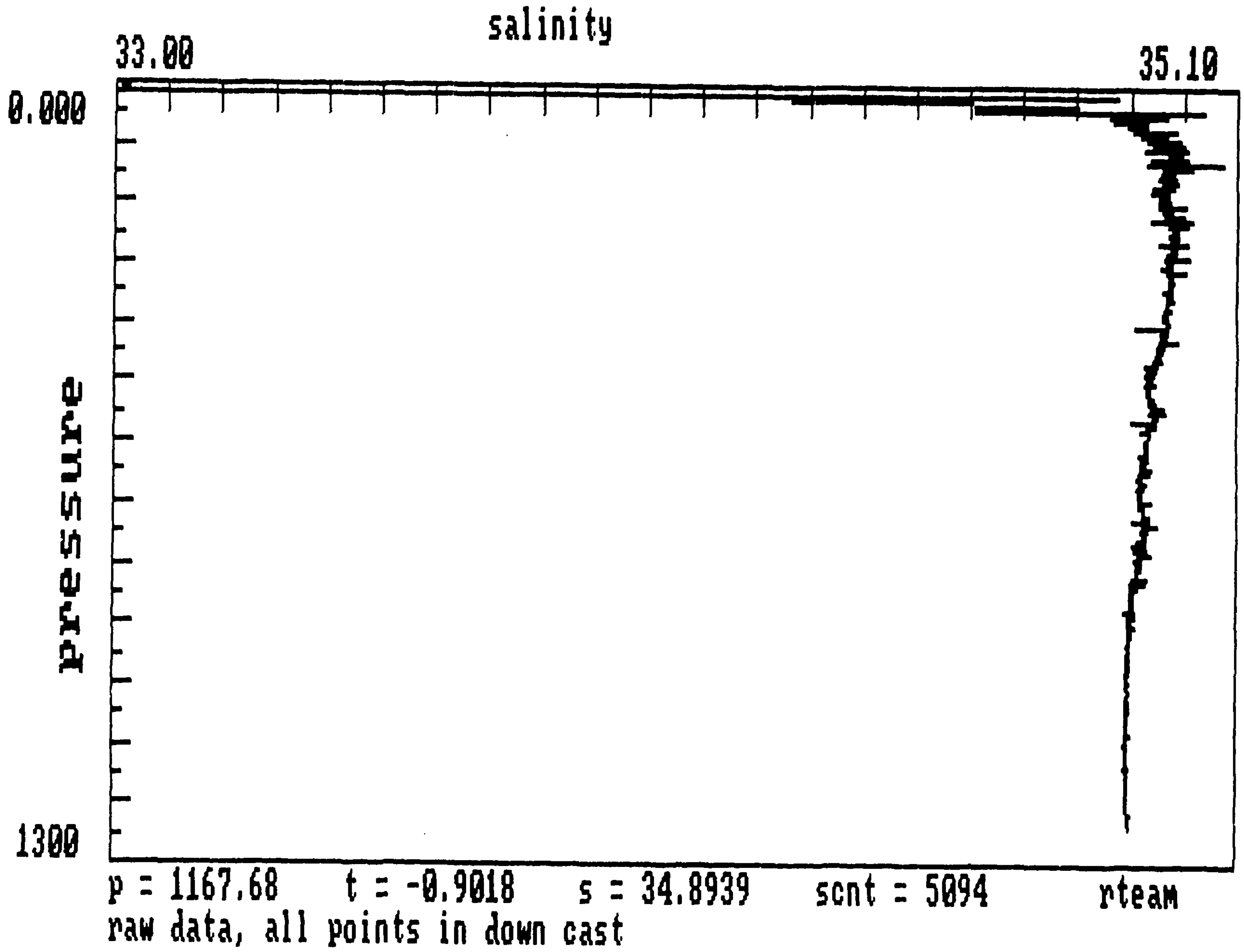


FIGURE F Salinity Versus Pressure, No Averaging

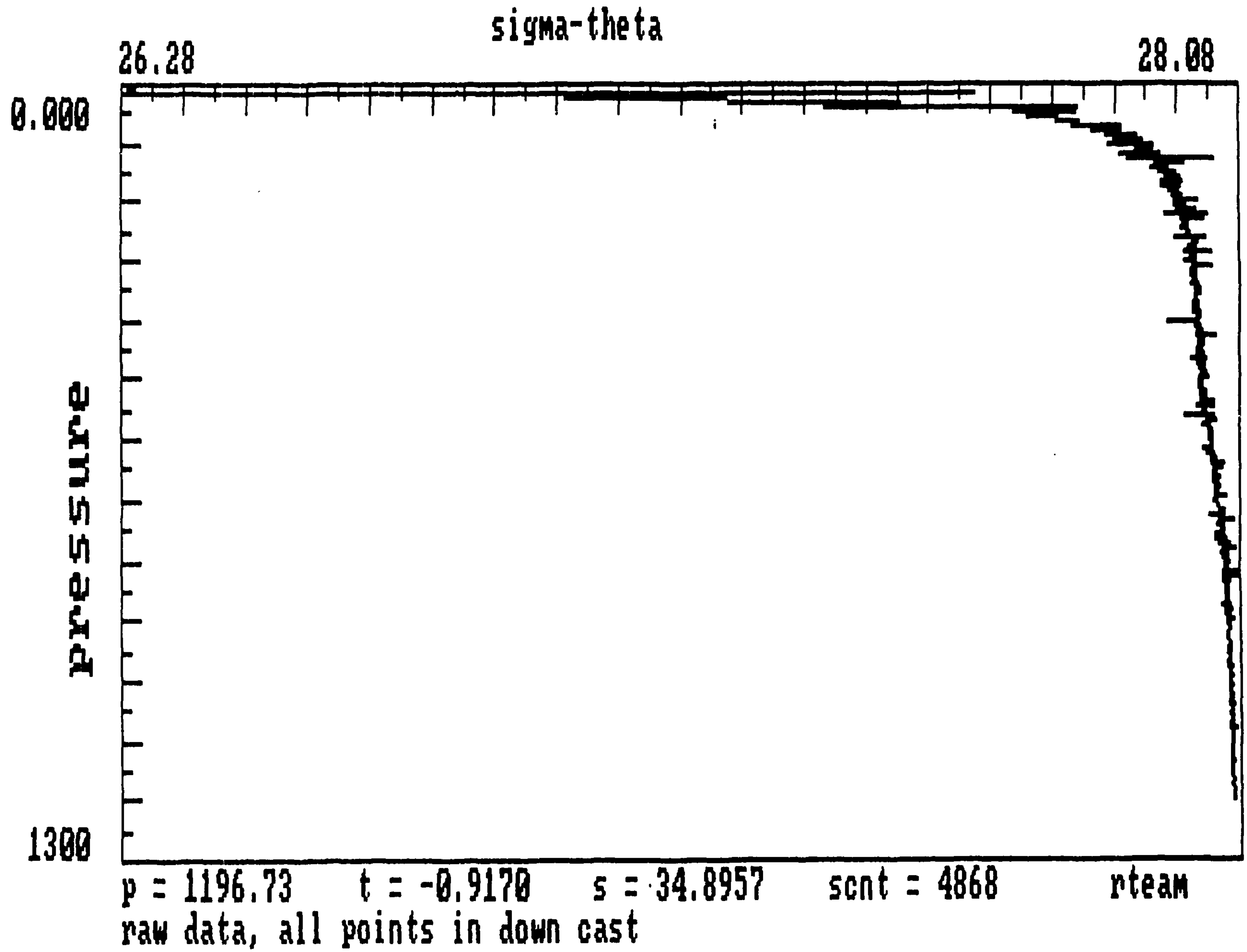


FIGURE G Sigma-Theta Versus Pressure, No Averaging

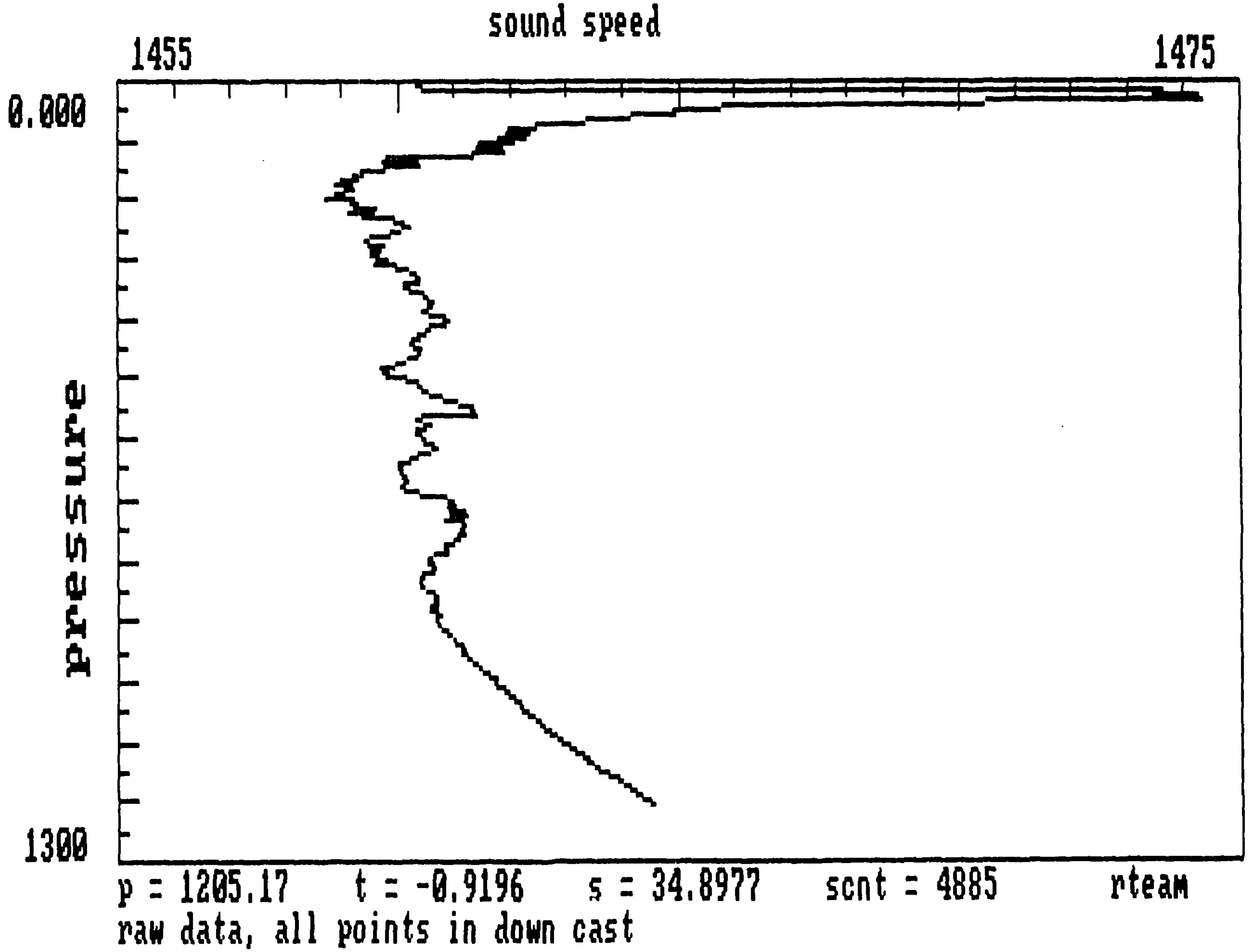


FIGURE H Sound Speed Versus Pressure, No Averaging

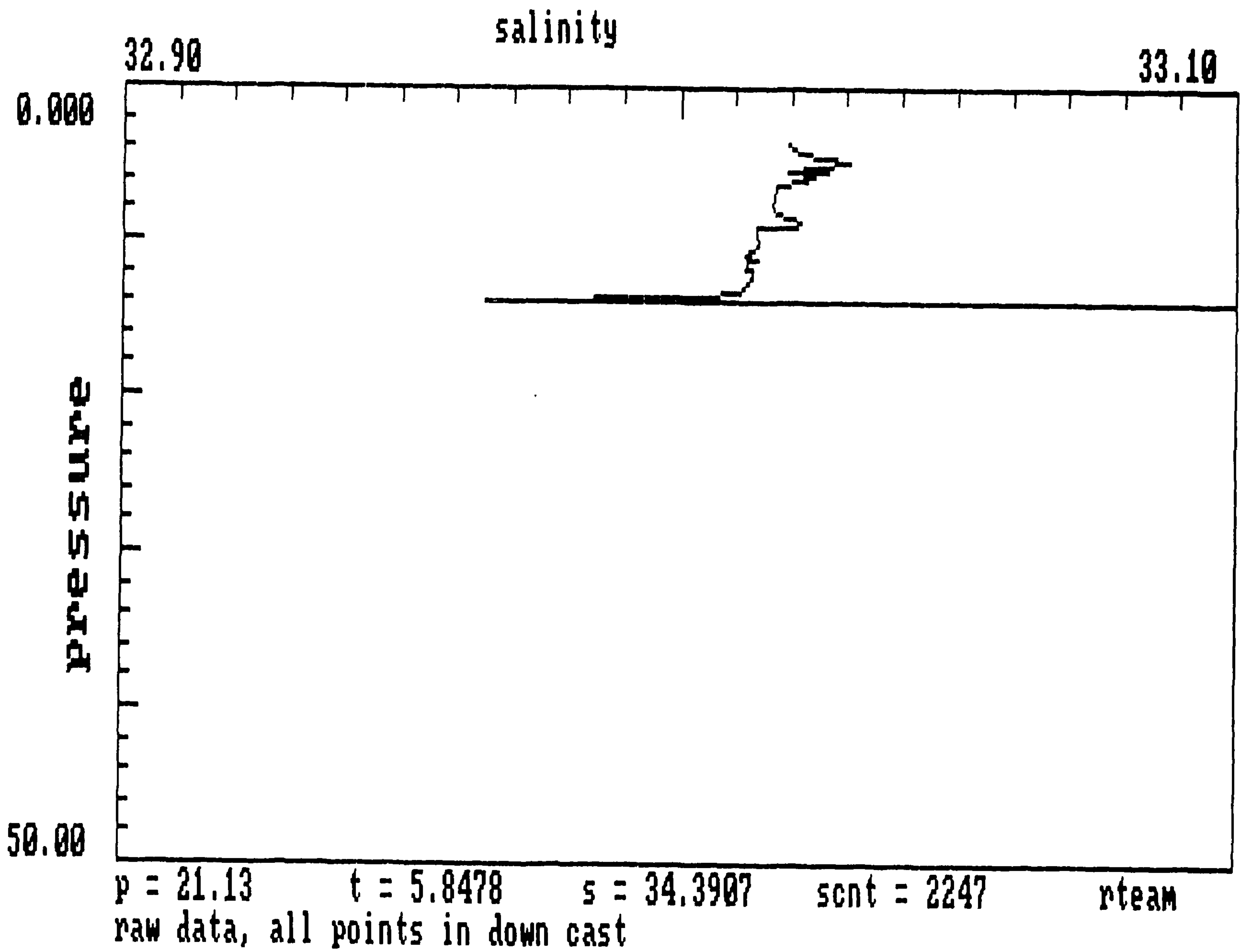
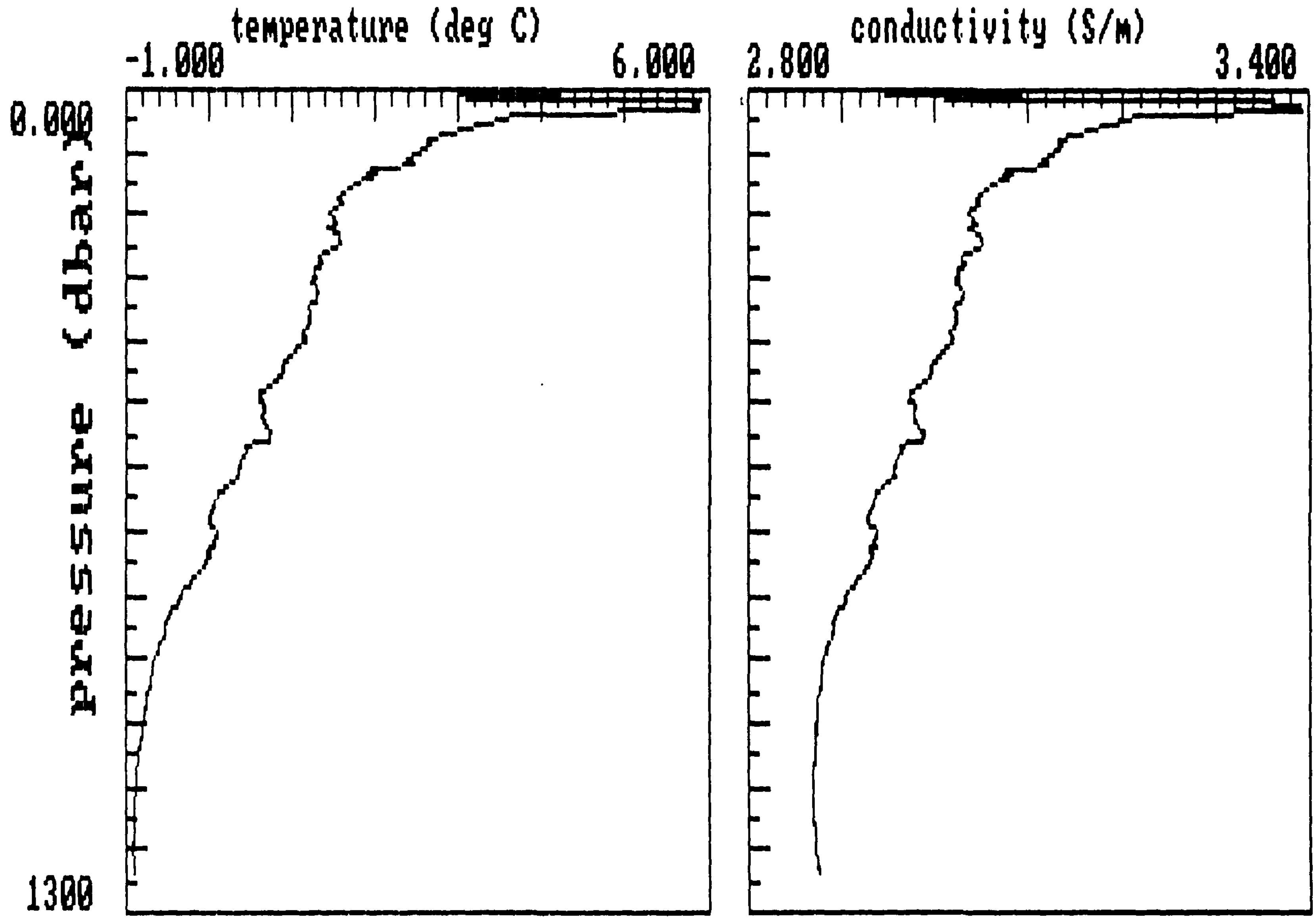
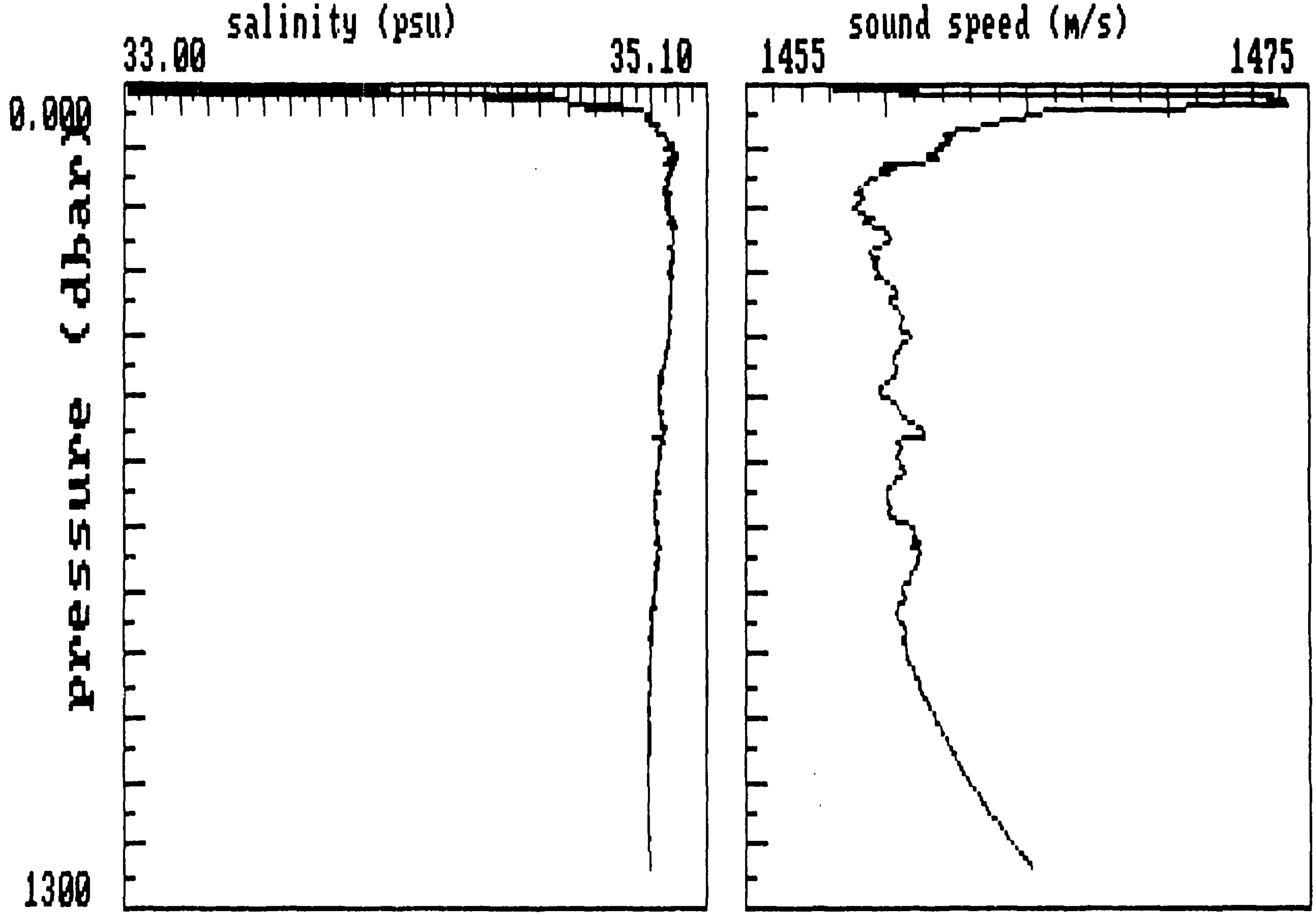


FIGURE I Salinity Versus Pressure For Just The Top 50m, No Averaging



rt2db-dn.avg: RTEAM: 79 28N, 6 52E, 24 AUG 88 2020Z

FIGURE J Temperature and Conductivity Versus Pressure For 2 Decibar Averaged Data



rt2db-dn.avg: RTEAM: 79 28N, 6 52E, 24 AUG 88 2020Z

FIGURE K Salinity and Sound Speed Versus Pressure For 2 Decibar Averaged Data

R-TEAM CTD STATION
2020Z 24 AUGUST 1988; ENDEAVOR 183
79°28'N, 6°52'E (mooring at 79°26'N, 6°48'E)

PRESSURE decibars	TEMP deg C	SALINITY psu	DENSITY sigmatheta	SOUND SPD m/s	CONDUCTIV S/m	DEPTH meters
10.11	3.1678	33.5439	26.6727	1463.02	3.04765	10.00
20.21	5.7988	34.4594	27.1511	1473.59	3.37142	20.00
30.32	5.4820	34.6661	27.3537	1472.75	3.36143	30.00
40.43	4.0662	34.7742	27.6007	1467.27	3.24406	40.00
50.54	3.4666	34.8768	27.7425	1465.05	3.19969	50.00
60.65	3.1370	34.9065	27.7981	1463.86	3.17331	60.00
70.76	2.8604	34.9177	27.8327	1462.86	3.15019	70.00
80.87	2.6652	34.9470	27.8736	1462.22	3.13576	80.00
90.98	2.6174	34.9657	27.8929	1462.21	3.13352	90.00
101.09	2.5170	34.9688	27.9042	1461.95	3.12537	100.00
111.20	2.3994	34.9784	27.9220	1461.61	3.11623	110.00
121.31	2.2858	34.9745	27.9285	1461.28	3.10636	120.00
182.00	1.5751	34.9613	27.9744	1459.14	3.04572	180.00
192.11	1.4833	34.9606	27.9806	1458.90	3.03811	190.00
202.23	1.4820	34.9685	27.9871	1459.07	3.03908	200.00
212.35	1.5257	34.9765	27.9903	1459.44	3.04399	210.00
222.47	1.4639	34.9774	27.9956	1459.33	3.03913	220.00
485.69	0.6123	34.9353	28.0200	1459.77	2.97382	480.00
495.82	0.6145	34.9348	28.0194	1459.95	2.97442	490.00
505.95	0.6602	34.9340	28.0160	1460.32	2.97878	500.00
516.08	0.6508	34.9345	28.0171	1460.44	2.97845	510.00
526.21	0.6498	34.9387	28.0206	1460.61	2.97915	520.00
992.82	-0.7744	34.8970	28.0623	1461.69	2.87450	980.00
1002.97	-0.7957	34.8971	28.0632	1461.75	2.87314	990.00
1013.13	-0.8039	34.8984	28.0647	1461.89	2.87298	1000.00
1023.28	-0.8146	34.8976	28.0645	1462.00	2.87246	1010.00
1033.44	-0.8206	34.8978	28.0650	1462.14	2.87241	1020.00

NOTES:
- instrument : Seacat SN 161291-16
- software : Seasoft 3.0g
- calibrations: factory
- operator : M.Briscoe

FIGURE L
Tabulated 10 Decibar Averages For The Top 120m
And The Depths Near The Instruments On The Mooring

Communications

Four different kinds of communication links were used to talk with Bob Summers at Ny Alesund.

From Tromso we spoke with him by direct telephone call:

080-27-111 mess hall at the Norsk Polar Institut

080-27-116 phone closest to his working site

From R/V ENDEAVOR we spoke with him via Radio Svalbar, and a patch to the phone numbers above. Radio Svalbard--callsign LGS--uses the frequencies 1736.0 kHz (ship receive) and 2456.0 (ship transmit). The ship station--callsign WVFQ--was an ICOM M700; Radio Svalbard was programmed into its position B-15.

From R/V ENDEAVOR we also spoke with him directly on VHF channel 16 (calling: 156.8 MHz), and switched to Channel 19 (working: 156.95 MHz).

The fourth successful link was Summers calling us on Radio Svalbard, but with the initial contact being made over 2182 kHz during our routine monitoring of it. We then switched to the 1736/2456 pair.

Finally, from the R/V ENDEAVOR we also attempted to call the Norsk Polar Institut directly on their frequency of 3524 kHz, but without success.

The additional communications from the R/V ENDEAVOR to other locations were on SSB and INMARSAT, including voice, fax, and telex. The SSB link (16587.1 kHz) was used to WHOI, as was INMARSAT fax and voice. Telex was used to communicate with the French base at Tromso; their number is 64025 SPACE N, Attention "Les Claudes" because both French researchers there are named Claude. SSB--calling on 2182--was used to speak with the French ship "Cryos" to discuss mooring and ice locations with Jean Claude Gascard.

ATS was not available on the cruise due to our high latitude and to an antenna problem on the ship. The INMARSAT link was also only possible at latitudes below about 78^{o} N.

This cruise would have been considerably more pleasant if ham radio had been aboard to permit phone patches home; the $10/minute charge on INMARSAT, when it was available, was psychologically constricting.

Miscellaneous

During the loading days in Troms, les Claudes asked if it might be possible to borrow any Niskin bottles from the ENDEAVOR, for use by Gascard on the Cryos. In fact, there were five 5-liter Niskin bottles aboard, but they were needed back at URI for the next cruise of the ENDEAVOOR on September 15. A radio conversation with Terry Joyce at WHOI resulted in Terry agreeing to cover the URI needs with WHOI Niskin bottles, so the five bottles on the ENDEAVOR were passed to Bob Summers at Ny Alesund to be given to Gascard when the Cryos called in there on August 26. I signed a chit on the ENDEAVOR accepting responsibility for the bottles, and prepared a chit for Summers to give to Gascard for him to accept responsibility for them. When the Cryos returns to France at the end of September, Gascard will ship the five bottles to Bill Hahn at URI. This three-way arrangement allowed for a French colleague to continue his work unimpeded without any undue effort or costs accruing to the other parties.

Information arriving from Summers at Ny Alesund and from Susan Tarbell at WHOI indicates that R-TEAM is quite successful. Not all the MF transmissions from the mooring to Ny Alesund are getting through, but about half of them are. Apparently, the currents at the site are quite variable and the floating wire antenna is not always oriented in the preferred direction. The ARGOS transmissions are getting through to WHOI and are being decoded successfully. We faxed Figures J, K, and L to Susan for her to compare with the temperature and conductivity data coming through, and she says it looks good. The currents also look good. The MF receptions at Ny Alesund are being repeated through ARGOS but have not yet been decoded at WHOI because the ARGOS ID information has not yet been give to Susan.

The plan now is to keep monitoring the incoming data and to prepare a methodology to compare data with satellite images so as to ascertain when the ice cover at the site takes place. There are loose schemes underway to keep data posted to a Telemail bulletin board, and for data exchange with Jens Meincke at Hamburg and Jean Claude Gascard at Paris. Gascard is installing SOFAR floats and listening stations in the Fram Strait area, and Meincke has Aanderaa current meter moorings in the area.

Meincke has agreed to attempt the recovery of the R-TEAM mooring from the POLARSTERN next summer, but has space for only one person for sure; two may be possible. The tradeoffs are that POLARSTERN is free to the project and can get through some pack ice to get to the mooring, but the cruise will probably be 30 days for one or two people with nothing to do the rest of the time, and the mooring is somewhat specialized so normal mooring recovery techniques are not really suitable. The ENDEAVOR has the R-TEAM recovery in its tentative schedule for next year, but cannot get through ice to get to the mooring if necessary.

APPENDIX A

Cruise Report

by

D.L. Powell

R/V ENDEAVOR 183

Tromso, Norway - Reykjavik, Iceland

August 21 - 30 1988

R-TEAM DEPLOYMENT CRUISE

Defense Systems, Inc.
7903 West Park Drive
McLean, Virginia 22102

The communication electronics was examined in Tromso August 19 and found to be in good condition. Both 28 volt battery packs had an open circuit voltage of 28.7 volts and performed identically under load therefore were not replaced. On Saturday, August 20 the bulkhead containing the antenna connectors was replaced as planned due to an oversize mounting hole for the HF antenna connector. Some large components were additionally secured to their PC boards with RTV and the mounting nut for the HF antenna was secured with epoxy. The internal wire harness was replaced after being freed for bulkhead replacement.

After work was completed on the communications electronics package it was tested for proper operation on the bench. The ARGOS transmitter output was 1.5 watts, measured with a Bird 4410A RF wattmeter into a 50 ohm dummy load. The HF transmitter output power was 50 watts, measured with a dummy load that transformed the output impedance of the transmitter down to 50 ohms, and a Bird 4410A RF wattmeter. At this time the HF transmitter was operating at 522.5 kHz.

Telephone contact with Bob Summers at Ny Alesund was made on the morning of Sunday, August 21. Bob Summers had assessed the noise environment at Ny Alesund and determined 537.5 kHz to be the best choice of operating frequency for the HF link.

As the R/V ENDEAVOR prepared to leave Tromso Sunday morning the operating frequency of the HF transmitter was changed to 537.5 kHz and tested. The HF transmitter power output was 70 watts at 537.5 kHz. The communications electronics package was installed in it's pressure housing approximately a half hour after the ship was under way.

During ascent module tests that were made Monday, August 22 in calm seas at 78° 28.5' N and 15° 25.9' E the HF transmitter was activated to determine if the ships HF receiver (a Drake MSR-2) could be used to receive the R-TEAM HF signal. As expected a very strong signal was received (range = 190m) and from this point on the ships HF receiver was used to verify HF transmitter operation.

After delivering an antenna preamplifier to Bob Summers in Ny Alesund early on the morning of Wednesday, August 24 the ascent module was put in the water approximately 4.5 N.M. from the receiving site at Ny Alesund
(78° 56' N and 11° 50' E) and four test transmissions were made the results of which are detailed in the R-TEAM HF LINK TEST LOG.

Later on Wednesday the ascent module was placed in the water at 79° 17′ N and 9° 18′ E and one HF transmission was made (Time: 12:00 GMT). These results are also in the test log.

The R-TEAM mooring was deployed in 1270 meter water at 19:33 GMT August 24. The location of the anchor was 79° 25.92′ N and 6° 47.91′ E. After deployment the ascent module made telemetry transmissions hourly, these transmissions were monitored aboard ship until 23:13:30 GMT August 24 at which time the R/V ENDEAVOR left the deployment site and headed for Iceland. The five transmissions monitored after deployment appeared normal
Subsequent contact with Woods Hole and Ny Alesund confirmed the telemetry system was functioning normally.

FACT SUMMARY

Cruise Personnel:

Peter R. Clay, WHOI
Henri O. Berteaux, WHOI
Alessandro Bocconcelli, WHOI
Melbourne G. Briscoe, WHOI, ONR
Ken Doherty, WHOI
Ken Fairhurst, WHOI
Ed Mellinger, WHOI
Pat O'Malley, WHOI
Dave Powell, DSI

Deployment:

Date:	August 24, 1988
Time:	19:33 GMT
Location:	79° 25.92' N
	06° 47.91' E
Depth:	1270 meters
ARGOS transmitter output power:	1.5 Watt
HF transmitter frequency:	537.5 kHz
HF transmitter output power:	70 Watts
Location of receive site at Ny Alesund:	78°56' N
	11°50' E
Bearing from receive site to mooring:	300° 30'
Distance from receive site to mooring:	64.5 n.mi

APPENDIX B

RTEAM MOORED STATION LOG

Station Number

MOORED-STATION LOG

Set

Anchor in Water — Date 24 AUGUST 1988

Time 1934 Zone Z

Lat. 79° 25.92' N Long. 6° 47.41' E

Obsvr./Recdr. H.O. BERTEAUX

Watch Checked: Before X After

Mooring Set By PETER CLAY

Ship & Cruise No. ENDEAVOR, #183

Recovered

Release Fired — Date

Time Zone

Lat. Long.

Obsvr./Recdr.

Watch Checked: Before After

Retrieved By

Ship and Cruise No.

Loran C Readings at Setting: 79° 24.67' & 06° 47.23' E (unreliable)

Depth Rec. Reading 1300 fm. (m) Depth Corr. * ~~1269~~ −31m Corr. m. 1269 m.

Float Depth 75 m. Matthews Area New Table NP 139 ~~4~~ 4 Mag. Var. 7° W

Mooring Purpose, Array Designation & No. RTEAM MOORING, REAL TIME ARCTIC TELEMETRY FROM UNDER ICE

Contract Number(s) 10/135.00

Location FRAM STRAITS Intended Duration (1) YEAR Actual Days at Sea

Main Float Type SYNTACTIC FOAM Color(s) INT. ORANGE Markings RTEAM

Numbers of Sphere Clusters 1 Total No. of Spheres 26 Hard-Hat Colors and Types HALF ARE NORMAL RIBBED YELLOW & HALF ARE BEER KEG STYLE YELLOW

Wire, Rope CONSOLIDATED PROD. DOUBLE ARMORED E/M CABLE TO 1000 m, 5/16" KEVLAR & 1" NYLON BELOW

Radio Make & Ser. # NA Light Make & Ser. # NA

Freq. — Char. — White Light Flashing Every — Secs.

DACS ~~AMF~~ Release No 503427 Tested to 1500 m. ~~Recvr.~~ No. Enable Code 416040 Rel. ~~Command~~ Code 430746

Disable A Code 416025 Disable B 416063

Xpndr. Interr. 9 KHz B Khz (11 KHz Channel A) Reply 11 KHz B Khz (8.5 KHz Channel A) Remarks This is a dual channel EG&G DACS unit

Anchors: Cylinder(s) 4000 MACE Lbs. (Wet); Danforth NA Lbs. (Dry); Other —

Miscellaneous * Using Matthews 1264 m. corrected

Current meters and hydrophones equip. w/ FSK SAIL and connected through cable & connectors to umbilical and a top ascent module which rises up & down to transmit data via Argos and HF transmissions.

Station Number ________

Item No.	Length in Meters	Item	Time Over	Notes	Time Back	Notes	True Depth in m.	Data No.
1	66	HF FLOATING ANTENNA	1355	w/ parachute & Yale grip at end				
2		ELEVATOR MODULE	1358	soft chicken bridle left on				
3	220	UMBILICAL		20 foam floats attached *.				
4	3	2000# BUOY & MOORING COLLAR	17:24					
5	25	1/2" EM STEEL CABLE	17:24	break in jacket				
6	2.1	VMCM #23	17:25	Bands off 17:25				
7	1.5	HYDROPHONE #1	17:25					
8	95	1/2" EM STEEL CABLE	17:30					
9	2.1	VMCM #27	1743	Bands off 17:30				
10	298	1/2" EM STEEL CABLE	1800					
11	2.1	VMCM #25	1801	Bands off 17:45				
12	1.5	HYDROPHONE #2	1801					
13	493	1/2" EM STEEL CABLE	1840	o-ring holes & set screw holes missing 1 end				
14	2.1	VMCM #31	1840	Bands off 18:05				
15	1.5	HYDROPHONE #3	1840					
16	2	3/8" CHAIN	1840					
17	200	5/16" KEVLAR ROPE (ADJUSTABLE SHOT)	2000	200 M. slack				
18	1	ENGINEERING INSTRUMENT	2000					
19	2	1/2" CHAIN	2000					

Date		Comments
Aug. 24.	1	* Floats attached with 1st 484 from sphere end. Floats are 1 m apart
"	2	VMCM 31 DG O'Brien Termination no taps, no set screw hole, no o'ring viewing port.
"	3	18:40 E.M. Checks electronics through HD#3. Everything O.K.
"	4	19:34. Pack Ice approx. 2 miles North of anchor drop.
		Schedule for module was 6 hourly cycles followed
		by normal 24 hour cycle. Both HF and Argos
		transmissions were heard during the hourly cycles.
		Polyform float and polypro (250') were cut off

Item No.	Length in Meters	Item	Time Over	Notes	Time Back	Notes	True Depth in m.	Data No.
20	25	~~20~~ 26 17" GLASS BALLS	1920	26 GB				
21	2	1/2" CHAIN	19:34					
22	1	DACS ACOUSTIC RELEASE	19:34	# 803427				
23	5	1/2" CHAIN	19:34					
24	20	1" NYLON ROPE	19:34					
25	5	1/2" CHAIN	19:34					
26		4000# (AIR WEIGHT) ANCHOR + MACE PLATES	19:34					

Date	Comments
	during the 2400L surface time just as
	pack ice drifted down over the mooring at
	about 1 knot.
Aug 24	Release disabled (both channels) at ≃ 0030L Aug 25

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August 9, 1988

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16. Abstract (Limit: 200 words)

The R-TEAM mooring was deployed on August 24, 1988 at the coordinates of 79° 25'.92 N and 06° 47'.91 E. This technical report describes the mooring as set and the deployment procedures.

17. Document Analysis a. Descriptors

1. Moored satellite telemetry buoy
2. Arctic environmental mooring
3. Tethered ascent module

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

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